Viktor Kaplan: his life and work

By H. Häckert

The Austrian engineer Viktor Kaplan was born 100 years ago this month. Although much development has taken place since his death in 1934, his ideas are still the basis of countless low-head plants throughout the world.

KAPLAN WAS BORN on November 27, 1876 in Styria, Austria. As one of his favourite pursuits in his early youth, he built water wheels and installed them in the mountain brooks near his home. After studying mechanical engineering at the Technical University, Vienna, he received his first industrial employment at the works of a diesel engine manufacturer. However, he soon fell into disgrace there because his ideas for the improvement of internal combustion engines were regarded as too revolutionary. Despite this early setback, he was requested soon after, to take over the position of a designer at the German Technical University at Brno, where one of his tasks was the construction of water turbines. Brno, the capital of Moravia, was then still a part of the Austrian empire. Kaplan started working there in the autumn of 1903. Existing copies of lectures and quite a number of publications give evidence of his improvements to the construction of Francis turbines, mainly of high specific-speed. Designers at that time were anxious to develop runners of increasingly higher specific speeds to obtain smaller, lower-priced turbines and generators for low-head water power so that it could be harnessed economically.

Kaplan also dealt with the then current theory of turbines and perfected it still further. He then set up a research laboratory for model turbines to investigate the theory on the basis of practical examples.

A small turbine with a 100 mm-diameter runner and a net head of 0·6 m permitted him to test a large number of models, as the small runners could be made in a short time with relatively simplicity.

In search of higher specific speeds, he developed a Francis runner with only four blades whose outer ends had the features of an axial runner. The next step was to design a purely axial-flow runner with a small number of blades, avoiding the cell-shaped space, but still with an outer band, so achieving a metric specific speed of 900*, twice as high as known at that time, and this with a substantially higher discharge capacity and a good efficiency. He retained the distributor of the Francis turbine. But tests proved that the efficiency curve of these runners against the discharge had high values only within a very narrow range. Theoretical studies of the layout of such a runner for half the discharge led him to the conclusion that the required blade angles of greater flatness could be obtained simply by turning the blades that were designed for full load. He also made another observation during his experiments: just as it was not necessary for the water in the runner to be "guided" through a large number of blades (as designers had so far assumed), it was equally unnecessary for the water to be "guided" up close to the runner blades. Thus there existed a "bladeless space" between the guide vane ends and the runner. Finally, he eliminated the outer band and so reduced the resistance in the runner even further.

Kaplan immediately consolidated all these findings in patent applications in the following order:

- Changeover from the Francis to the axial runner, December 11, 1912 in Austria;
- Adjustable runner blades, August 7, 1913;
- Adoption of a bladeless space between radial distributor and axial runner, September 16, 1913;
- Making the blade length shorter than the blade spacing, ie, a runner avoiding the cell-shaped space, October 6, 1913;
- There soon followed a patent for an elbow draft tube with a sharply bent outer contour but a gently rounded inner contour, evolved by Kaplan in his experiments.

The objective of the Kaplan turbine is to use the substantially higher energy at the runner exit with good efficiency over as short a distance as possible. Kaplan filed patent applications for all these and many other inventions, not only in Austria but also in all countries where water resources were utilised. During his time as a lecturer, he had familiarized himself with the world's water power resources and so he knew the importance of his, the "Kaplan" turbine, as he soon named it.

At the end of 1913 Kaplan was appointed Professor for water turbines at the Technical University. His next step was to invite experts from turbine manufacturers to Brno to demonstrate his model turbines at the test rig and to let them make their own measurements. While all were deeply impressed by such a high specific speed and the efficiency, Kaplan demanded a considerable amount of money simply for his patents, without disclosing his

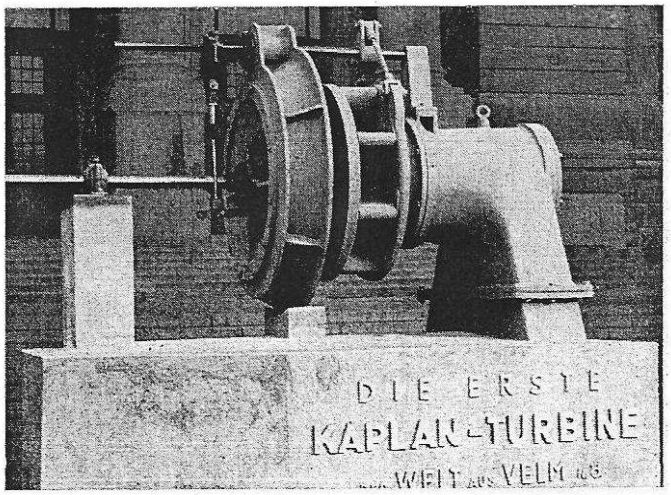


Fig. 1. The world's first Kaplan turbine, on display at the Technical Museum in Vienna. It was built in 1919 by the Storek steel mill, Brno, and operated under a head of 3 m at a speed of 500 rev/min. Photograph courtesy of Technical Museum Vienna.

*Speed of a geometrically similar turbine with 1 h.p. at 1 m head

design; therefore, most manufacturers regarded this as too high a risk and adopted a policy of wait and see; only a Swedish company and a Norwegian manufacturer agreed to take out contracts with him.

In August, 1914, World War I broke out and most civilian activities were impeded; thus work on the Kaplan turbine did not make any progress. When the patents had ultimately been disclosed, Kaplan was faced with a long series of vexing disputes; many objections were raised, and his patents were attacked by the presentation of earlier publications on the features of similar runners or turbines. Not even the tests which a group of German and Swiss turbine manufacturers conducted on an experimental turbine according to Kaplan's drawings produced any progress, as Kaplan, for obscure reasons, had given them drawings for a fixed-blade turbine, ie, a propeller runner. New quarrels and patent litigations followed, until the German Supreme Court at last rejected the objections and granted him the patents. Many years had been wasted.

From mid-1917 Professor Kaplan again devoted himself to lively literary activity: in journals of various fields he informed the technical world of the features of his turbine, without however disclosing constructional details.

When the war ended in 1918, the Austrian monarchy collapsed. Bohemia and Moravia, thus also Brno, fell to the newly-established state, Czechoslovakia, but the German Technical University was left to continue its activities, as the Austrian staff opted for the new state.

At about that time, Kaplan finally succeeded in obtaining the first order for a double-regulated Kaplan turbine; it was delivered early in 1919 by Messrs Storek, a German family-owned company. The output measurement of this small machine (Fig. 1) of 35·3h.p. at a head of 3 m with a runner diameter of 0·6 m showed the now familiar flat η-curve with $\eta > 81$ per cent at 36 to 106 per cent of the discharge, and a maximum of 86 per cent. This remarkable result appeared in several publications, but only with the drawing showing a turbine with fixed blades.

Suddenly, interest in Kaplan's invention re-awoke, even though it was initially mixed with scepticism about the accuracy of the measurements. Such a high specific speed of 750 and favourable η-characteristics were regarded as sensational. Turbines with such properties obviously had a good market. Storek started building Kaplan turbines and soon had a number of orders on his books. A group of German and Swiss manufacturers founded the Kaplan Turbine Consortium* with Voith as a sponsor and concluded licencing agreements with Kaplan.

The Voith hydraulic research centre conducted tests and furnished the members of the group with additional design details; but soon confidence in the Kaplan turbine again was shaken and put to a severe test. Some of the

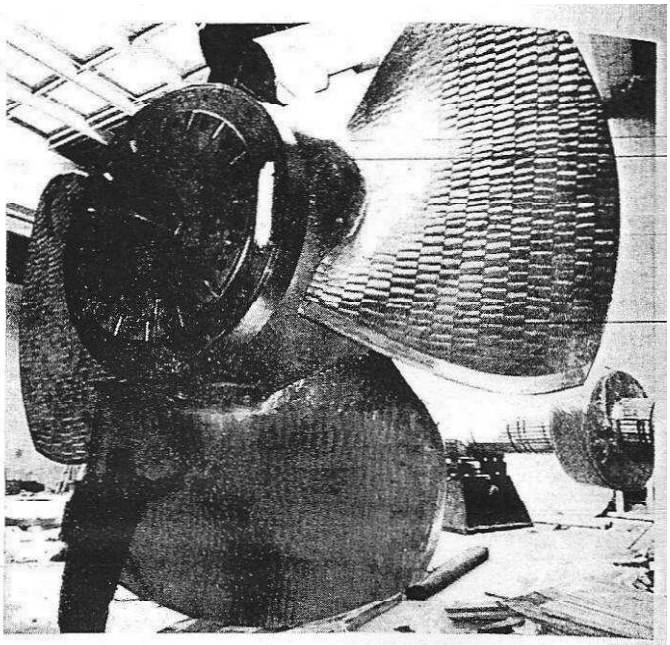


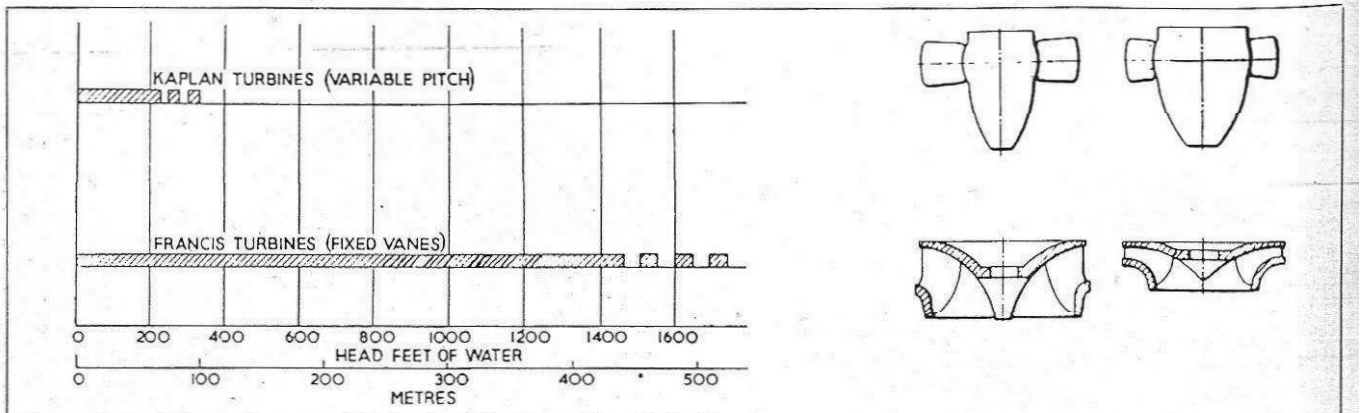
Fig. 2. A modern Kaplan runner for the Altenwörth scheme on the Austrian Danube. It will operate under a 13·6 m head at 103 rev/min and develop 44MW. The runner diameter is 6 m. Courtesy J. M. Voith.

Kaplan turbines that Storek had already delivered displayed very strange phenomena—loud abrupt noises with pitting of the blades and in the draft tube. This phenomenon was cavitation—at that time still unknown to the turbine manufacturers—but it only affected turbines operating at high heads and excessive suction heads. These large-scale units had been built on the basis of model tests under net heads of 1 m only, where cavitation could not occur: among the affected units was a turbine with a head of 6 m, a suction head of 3 m and a specific speed of 1400.

Just at that time, Kaplan fell seriously ill and this compelled him to interrupt his work for a long time. He was deeply depressed by the failures and unable to help. An ex-naval officer who worked at Storek's identified the phenomenon as cavitation which had already been observed on ship's screws. Therefore, tests under a high net head and a variable suction head were immediately conducted. In addition, the licencees and some university professors included cavitation in their experiments. Some years were required to repair the damage to the turbines, and the turbine manufacturer had to bear a heavy cost.

Then there came the desired turning point: in the autumn of 1923, the Voith works announced they had successfully commissioned two 1100h.p. Kaplan turbines ($H = 6$ m. $D = 1·9$ m diameter and a specific speed of 900) and installed them in the Siebenbrunn power station of an Austrian paper mill. No sooner had the good news about these

*Ateliers des Charmilles, Geneva; Escher Wyss, Zürich and Ravensburg; J. M. Voith. Heidenheim and St. Pölten, and some firms which no longer exist.



Comparison of the maximum working heads of Kaplan and Francis turbines

turbines somewhat subsided than more successes were recorded. In 1925, the Swedish licensee, KMW, also successfully commissioned the Lilla Edet Kaplan turbine ($H = 6{\cdot}5$ m, $D - 5{\cdot}8$ m diameter, 11 200h.p., specific speed 650) which it had delivered to the Swedish State Waterfall Authority. There still remained some scepticism about the operational safety of the runner blade adjustment, but after a period of operation the inspections at Siebenbrunn and Lilla Edet revealed that there had been no wear. More and more orders for Kaplan turbines were placed, some with the other licencees, who could now gain some experience of their own. All licencess had, of course, previously conducted model tests.

When a large power station for a discharge of 1000 m^3/s was planned at Ryburg-Schwörstadt on the upper Rhine, there was no doubt that Kaplan turbines only were to be used. The members of the Kaplan Turbine Consortium* daringly built four machines of about 40 000h.p. each with 7 m-diameter runners, another world record after Lilla Edet. In 1931, Ryburg-Schwörstadt was in full operation.

It was also in that year that Professor Dr-Ing. Dr.techn.e.h. Kaplan, who had not entirely recovered from his serious illness, had to take leave from the Brno university as he was physically unable to withstand the stress. A few years later, on August 23, 1934, he died at his home near the Attersee in the Salzkammergut in Austria, his home country. He had lived to see the victory of his idea in which he had invested all his strength, and died highly honoured by the technical world. Meanwhile, the wish which his friend and biographer, Professor Lechner, expressed at the end of his book has come true many times: "May a big power station on the Danube, equipped with Kaplan turbines, be created". Fig. 2 shows one of the Kaplan runners for a maximum of 44 MW under a net head of 13·6 m of the Altenwörth power station which is at present under construction. (See *Water Power and Dam Construction,* January 1976.)

Even if some of Kaplan's inventive conceptions were known beforehand and some of his ideas have never gained or meanwhile lost significance, it is entirely due to him that in the combination of several of these ideas he showed the technical world an approach to the economic low-head turbine, an approach which his licencees could continue. ■

*Charmilles, Geneva; Escher Wyss, Zürich and J. M. Voith, Heidenheim (two turbines).

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Improvement in transport of floating debris

By E. Bisaz*, K-C. Taubmann*, and P. Fischer**

With the deep-seated turbine intakes of run-of-river powerplants utilising bulb turbines, an almost currentless zone at the upstream face gives rise to the problem of the inadequate transport of floating debris to the upstream face or the trashrack of the powerhouse. In those cases where piers protrude from the upstream face, vortices may occasionally occur which are sometimes accompanied by the suction of air and floating debris into the turbine intake.

DURING THE past 15 years the use of bulb turbines in run-of-river powerplants has gained increasing acceptance even with units of relatively high capacity. In these plants the preferred horizontal-shaft turbine arrangement results in relatively deep-seated turbine intakes with correspondingly high upstream faces above the intake bellmouth. These faces have the same inclination as the trashrack and the rails for the mechanical rakes. The water flow in front of the intake is, therefore, limited to the reach of an imaginary upstream extension of the intake bellmouth up to the storage water level.

As shown in Fig. 1, in the area between the upstream face and the extension, which may be described as a separation layer; this limitation gives rise to a zone in which there is a relatively slow counter-clockwise rolling movement about the horizontal axis. On the surface within this area, a movement of water in the upstream direction occurs so that arriving floating debris is retained in the above-mentioned separation layer. This material comes to rest some metres from the trashrack or the front of the upstream faces; it is, therefore, out of the range of the mechanical rake (see Fig. 2) so that it must

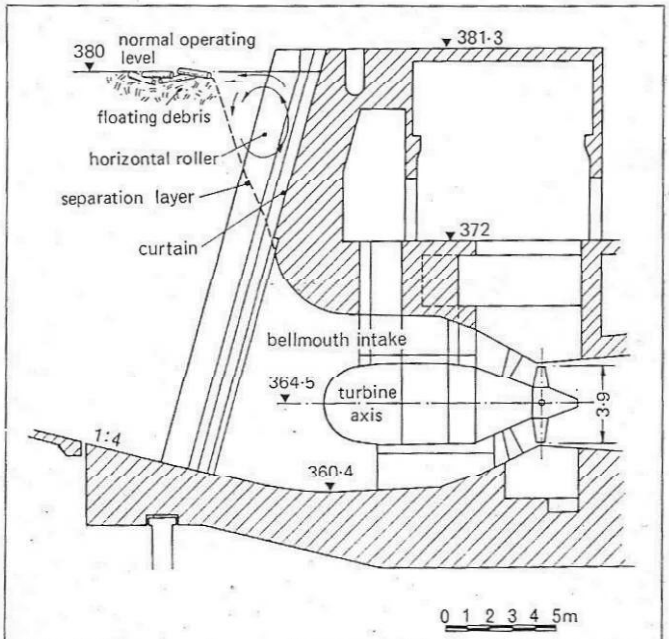

Fig. 1. The almost currentless zone between the "separation surface" and the upstream face of a deep-seated turbine intake (longitudinal section).

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